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Hydrogen Capture or Utilization in Mg/Fe Based Chemical Heaters

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Problem Background

- Flameless Ration Heaters (FRH) are used to heat Meals, Ready to Eat (MRE) and Remote Unit Self Heating Meal (RUSHM)
  - Upon activating with water, they release heat, steam, and hydrogen
- Need to
  - Capture or react the hydrogen to avoid explosive limits from being reached
  - Mitigate actual and perceived safety concerns with hydrogen presence
- Challenges:
  - Cost needs to be comparable with $10/RUSHM heater
  - Must destroy a lot of hydrogen (11.3 Ft^3) in a short time (45 min)
  - Must be lightweight and compact
  - Readily integratable with RUSHM heaters

The flameless ration heaters work by reacting water with Mg to release a mixture of steam and hydrogen gas

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RUSHM Activation

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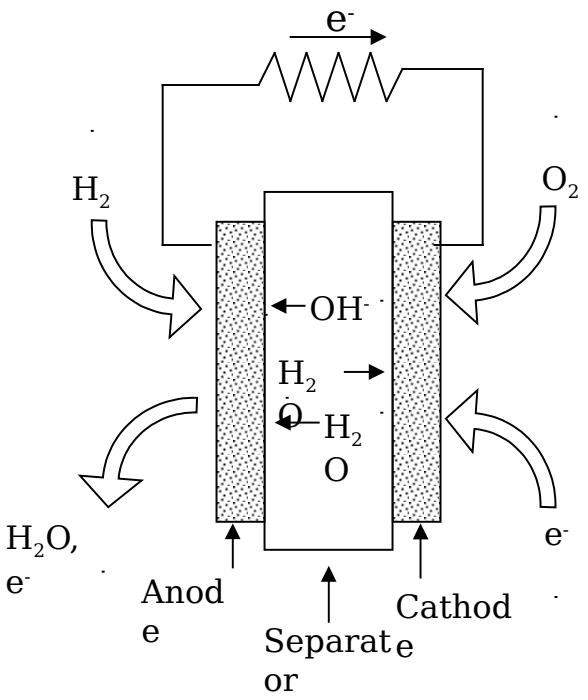
Technical Approach to Mitigating H_2 from the RUSHM

- A fuel cell may be used to react the hydrogen
  - Produces waste heat, electricity, and water as products
  - Electricity may be used in a resistive heater or to power electrical conveyances (*e.g.*, recharging batteries)
- Historically, there has been slow development in transitioning low volume, aerospace fuel cells to high volume, commercial fuel cells
- Traditional challenges in commercial fuel cells over the past 30 years
  - System is too expensive ($1500 to $10,000/kW)
  - Fuel source (hydrogen) does not readily exist
  - Reliability is unproven
- Our approach overcomes these issues
  - Hydrogen comes from the flameless ration heater
  - A 30 minute operational lifetime is completely feasible right now
  - Cost for the system including materials and manufacturing meet the Army's target of $10/RUSHM

Alkaline Fuel Cell Approach Minimizes Cost

- Presently used on-board the Space Shuttle
- Extensions to terrestrial applications difficult
  - Electrolyte leakage, corrosion, and carbonate buildup limit lifetime and increase cost
- However, for the RUSHM application
  - Longevity not required, only 45 min
  - Electrolyte can be stored dry until activated with water
  - Negligible CO_2 adsorption in 45 min
  - Inexpensive materials may be used for the single use application



Anode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Total: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

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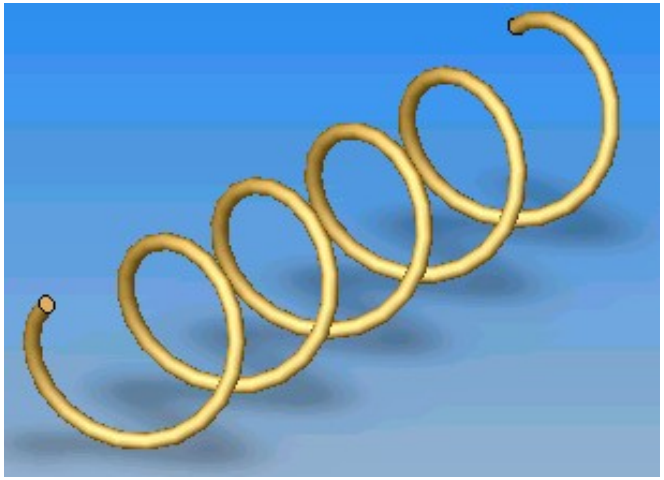
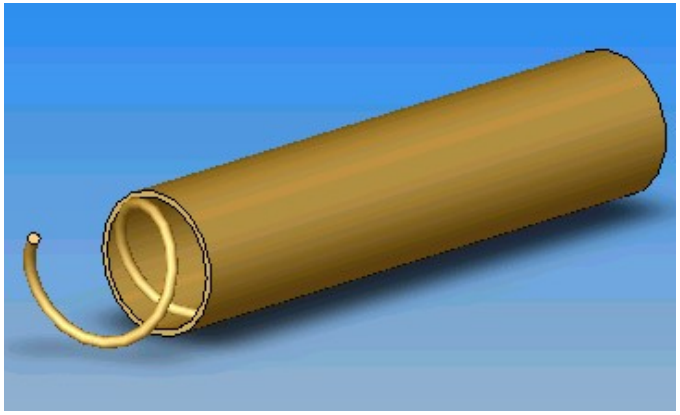
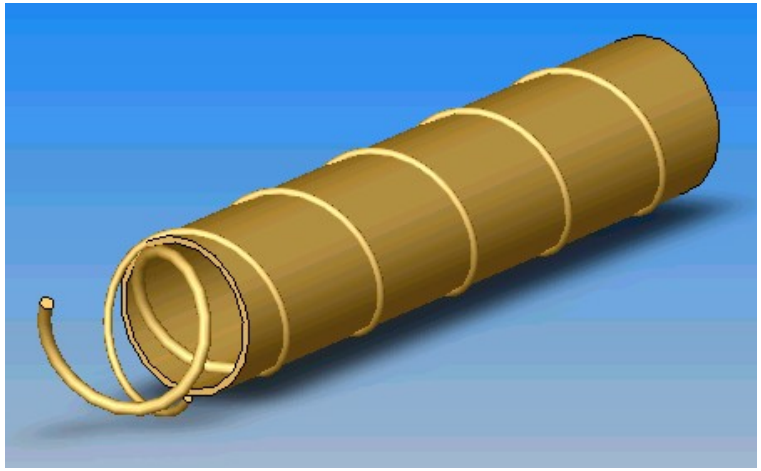
FCord™: A Tubular Alkaline Fuel Cell That Produces Heat Along the Cell



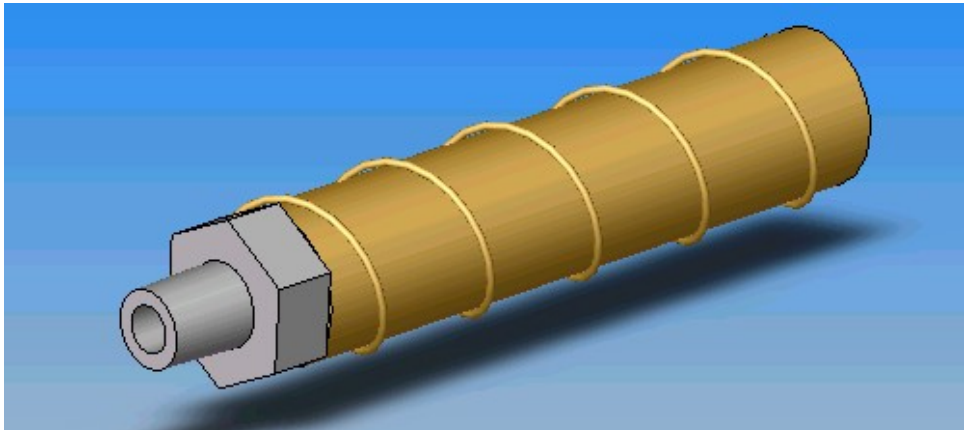
1. Coil Anode Ni Wire



2. Wrap With Separator and KOH



3. Wrap Cathode Ni:Cr Wire



4. Insert H2 Fitting and Connect Electrodes

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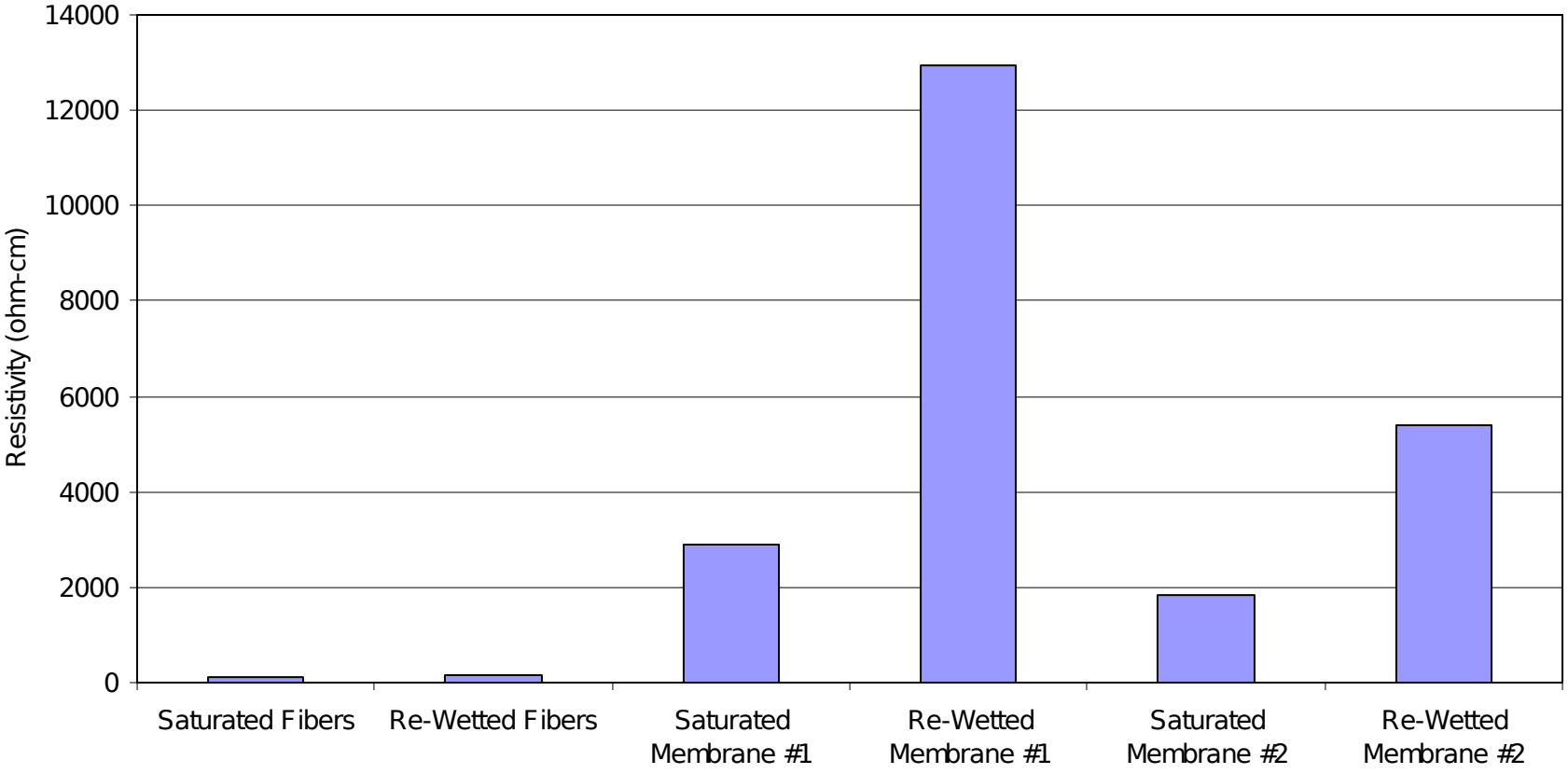
Separator Development

- Necessary requirements for the separator are:
  - Can be wetted with electrolyte and dried out to “turn it off” until activated
  - Can be activated with water quickly giving adequate ionic conductivity similar to 30% KOH
  - Does not allow hydrogen gas to permeate through it
  - Is thin enough to minimize the ohmic drop through the separator
  - Can be assembled into a tubular form
- Good candidate choices include
  - Hydrophilic fibers
  - Microporous membranes

Re-Wetted Hydrophilic Fibers Maintain Lower Resistance Than Microporous Membranes



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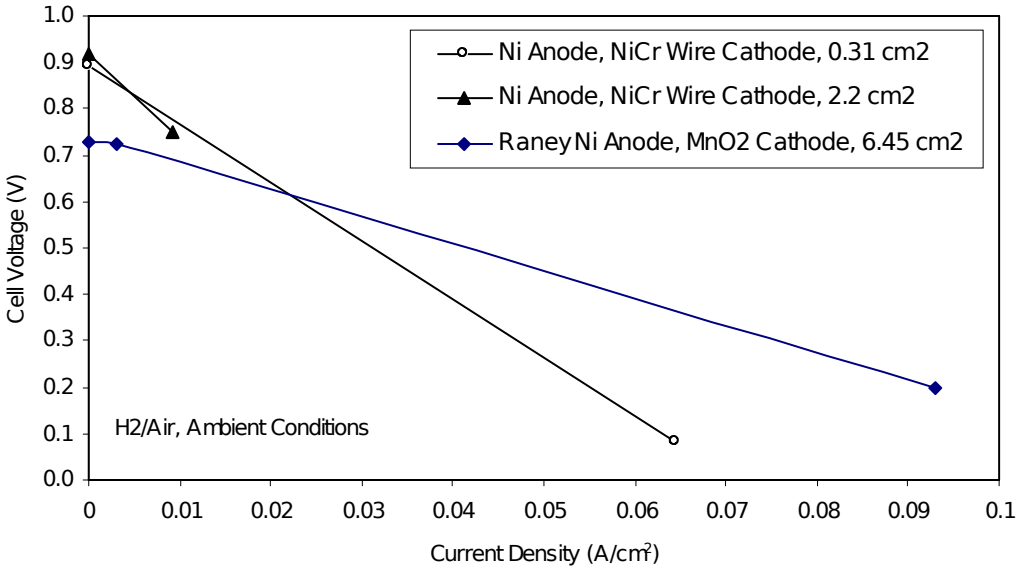
Higher Fuel Cell Performance Obtained With Improved Electrode Materials and Designs

- Porous gas-diffusion electrodes improve performance
- Can use traditional battery and AFC materials such as Raney Ni (anode) anc MnO_2 (cathode)
- Combine with high surface area carbon and PTFE over a current collector
- Forms a mixed hydrophobic and hydrophilic gas diffusion electrode



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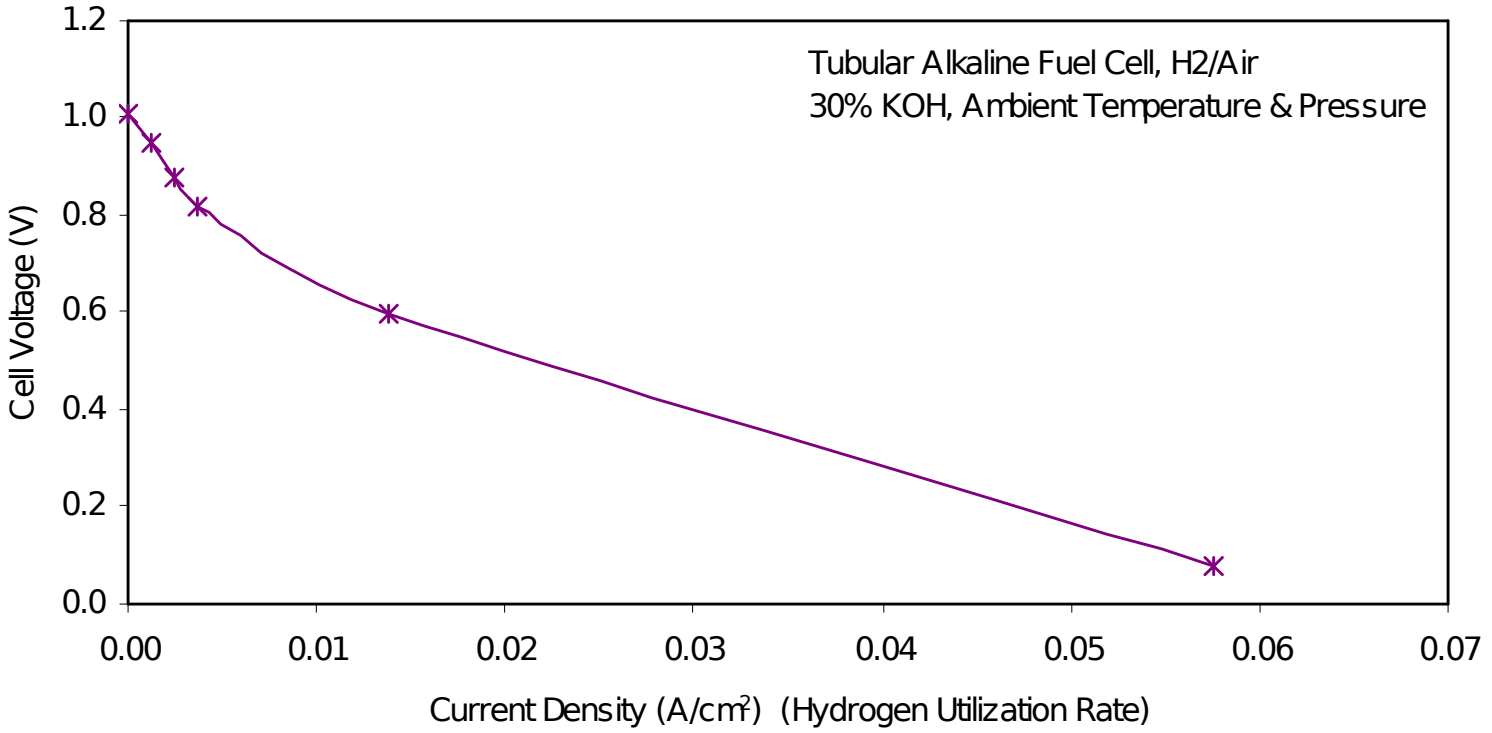
Initial Polarization Results in a Tubular AFC Show Promising Performance



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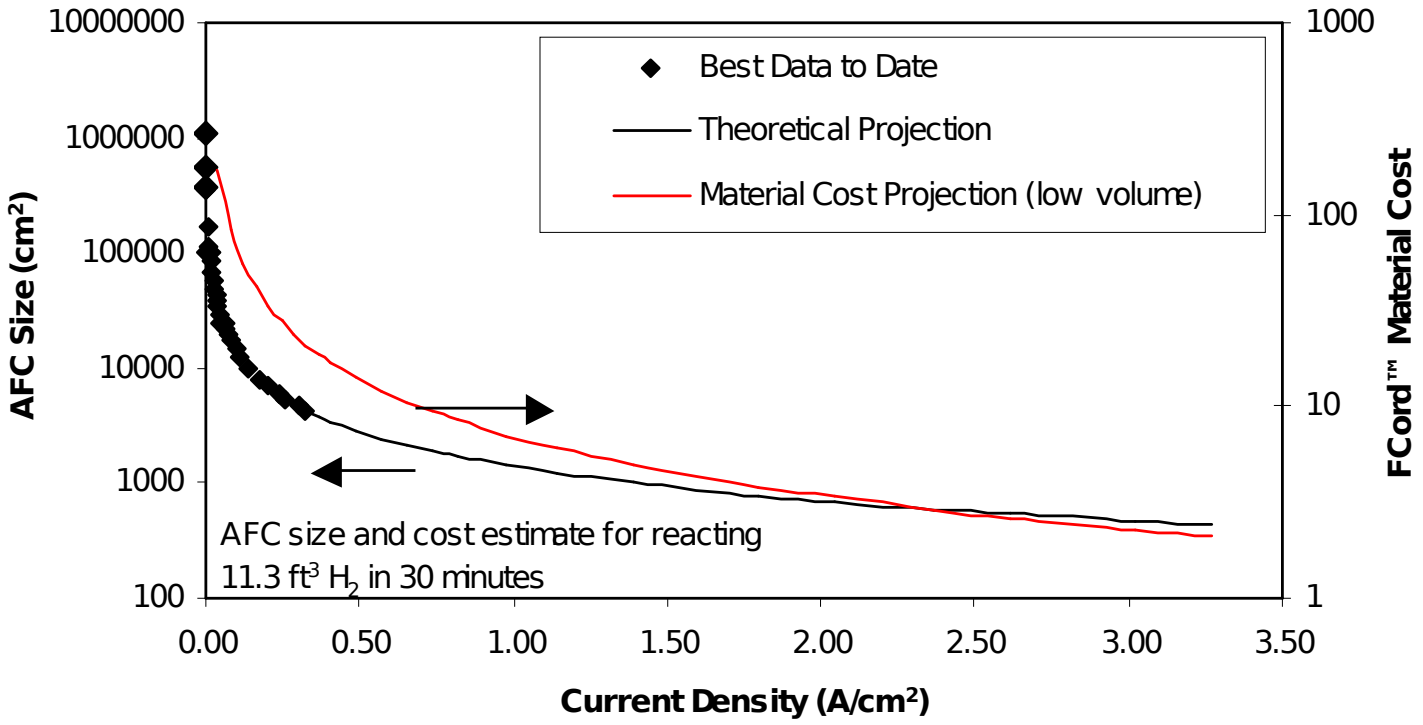
Operation at Higher Current Density Will Minimize Size and Cost of the FCord™



Achieving an operational goal of 2 A/cm² will keep the cost less than $10/unit at a mass of 100-200 grams

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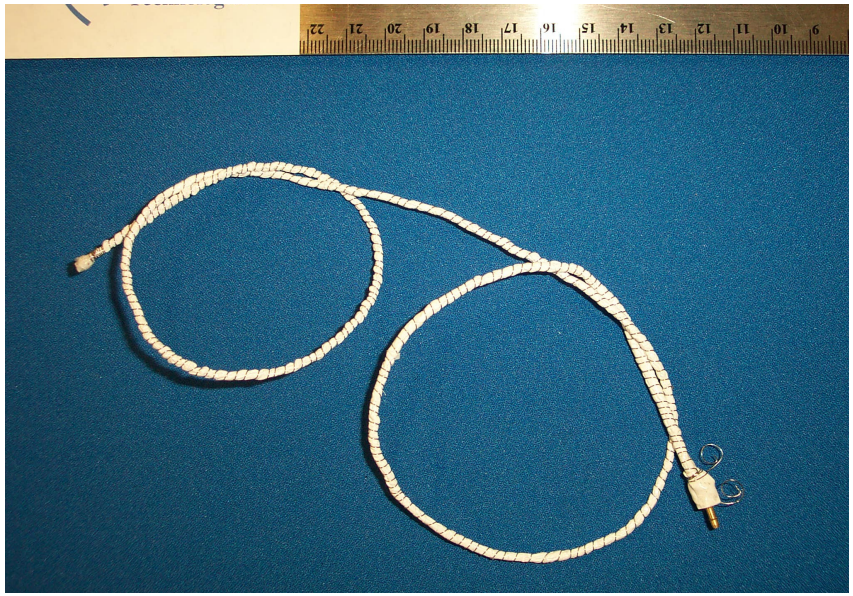
FCord™ Summary

- Shown that flexible and lightweight tubular AFCs may be fabricated
- Shown the NiCr may be used as a dual functioning electrode and heater
- Demonstrated that the electrolyte may be dried out and quickly activated with water
- Assessed low volume material costs and fabrication approaches to give a cost less than $10/RUSHM unit
- Conducted preliminary sizing and integration of the FCord™ into the RUSHM
- Further optimization underway



Patent Pending

- 85 mil diameter, 24” long prototype
- Operation at 2 A/cm^2 will produce 40 Watts
- Mass of 2.1 g and 2.3 cc volume

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